PATENT SPECIFICATION

(11) 1 206 196

DRAWINGS ATTACHED

(21) Application No. 13973/68 (22) Filed 22 March 1968

(31) Convention Application No. D52653 II/63c

(32) Filed 29 March 1967 in

(33) Germany (DT)

(45) Complete Specification published 23 Sept. 1970

(51) International Classification F 16 h 45/00

(52) Index at acceptance
F2C 10C 16H 16X 23
F2D 13C7A 13G1C 13K1A 13N
G3P 16E2 22 24J 5

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(54) INFINITELY VARIABLE HYDROSTATIC TRANSMISSION FOR VEHICLES, ESPECIALLY FOR MOTOR VEHICLES

(71) We, DAIMLER-BENZ AKTIENGESELLSCHAFT, of Stuttgart-Untertürkheim, Germany, a Company organised under the laws of Germany, do hereby declare the invention for which we pray that a patent may be granted to us and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention concerns an infinitely variable hydrostatic transmission in power-driven vehicles, especially but not exclusively motor vehicles, comprising an axial-piston pump driven by the power unit of the vehicle, and at least two axial-piston motors, at least one of which is permanently connected to the output shaft and at least one can be optionally coupled with the driven shaft or uncoupled therefrom.

Some vehicles need a transmission with a particularly large reduction range with ratios, say, from 1:1 to 1:16. Such ratios can be obtained with a hydrostatic transmission of the kind mentioned above, several motors being employed in known manner if large output torques have to be furnished. In a known such transmission, individual motors are designed with different reduction ratios and are connected to the output by clutches. When the maximum permissible speed is reached, the motor concerned is uncoupled. This uncoupling, and the coupling, take place with zero delivery volume in order to ensure shock - free uncoupling and coupling. A disadvantage of this transmission is that axial-piston motors have poor efficiency when the delivery volume is small. If a vehicle has to remian for any length of time in a speed range involving a low delivery volume, the unfavourable efficiency becomes very noticeable.

An object of the invention is to eliminate the aforesaid disadvantage while still permitting shock-free motor coupling and uncoupling.

According to the invention, in an infinitely variable hydrostatic transmission in a vehicle, comprising an axial-piston pump driven by the power unit of the vehicle and at least two axial-piston motors, at least one motor is rigidly connected to the output shaft and at least one other motor can, while in a driving position, be coupled to the output shaft or uncoupled therefrom by a clutch, and the pump is arranged to be so adjusted on uncoupling of the said other motor, that the said one motor can furnish the output torque required.

In such a transmission, the motors still have a relatively high efficiency even on the uncoupling. Hence the vehicle can remain in a speed range involving a low delivery volume for a fairly long time without trouble. Torque jolt is prevented by the aforesaid pump adjustment simultaneously with the uncoupling. The angle of tilt of the pump is so adjusted that as the said other motor is uncoupled, the said one motor can furnish the whole of the torque required, because of the higher pump pressure.

Suitably, a clutch operated by auxiliary power is associated with each said other motor and the auxiliary power is controlled automatically in conjunction with the angle of tilt of the motor. Uncoupling may take place at an angle of approximately 4°. With a larger angle, the said other motor in question is coupled and with a smaller angle uncoupled.

The angles of tilt of both the pump and the motors may be controlled together by cam or slotted plates from a servo-assisted operating lever. Transmissions in which, in the driving-off position, the pump has its smallest, and the motors their largest, angle of tilt, may be controlled so that firstly the pump alone is brought to its maximum angle of tilt and then each said other motor has its angle of tilt reduced to the uncoupling point. At that point, the angle of tilt of the pump is also reduced to a value dependent on the torque difference and, after uncoupling, is restored to its maximum value. The aforesaid one motor is only restored to its minimum angle of tilt when the pump has reached its

maximum angle for the second, or last, time.

The tilting members of the pump and motors may be connected through linkages to respective slot or cam plates on a common shaft rotatable by a servo-assisted piston controllable by an adjusting member. Instead of employing a common shaft, other forms of connection can be provided between the individual slot or cam plates. Thus the or each said other motor may be connected to the output shaft through intermediate gearing and a clutch which can be engaged against spring force by means of auxiliary fluid power controlled by a valve which, under the spring force, connects the clutch to the supply line for the fluid and, when actuated by the said motor, connects the clutch to a fluid-relief connection.

To enable the invention to be readily understood, reference is directed to the accompanying drawing, in which:

Figure 1 is a diagrammatic illustration of one embodiment of the invention by way of example, and

Figure 2 is a diagram by reference to which the manner of operation is explained.

Referring to Figure 1, the power unit 10 of a vehicle, an internal combustion engine for example, is connected through a drive shaft 11 to a hydrostatic transmission 12 which drives the rear axle 14 of the vehicle, for example and as shown through a driven shaft 13. The transmission 12 comprises an axial-piston pump 15 and two axial-piston motors 16 and 17. All the axial-piston units work with adjustable swash plates hereinafter referred to. They are connected with one another by the usual suction and pressure pipelines, which for the sake of clarity have not been illustrated.

The motor 16 is permanently connected rigidly with the driven shaft 13. The motor 17, however, acts on the shaft 13 through an intermediate gearing 18 and a disengageable clutch 19. The clutch 19 can be engaged by a pressure medium acting against a spring (not shown). For this purpose, a control slide valve 21 is disposed in the line 20 supplying pressure fluid to the clutch 19. Normally, the valve 21 is held by a spring 22 in such a position that the line 20 is open and the clutch is thus engaged. The valve 21 is so disposed, within the range of movement of the swash plate 23 of the motor 17, that when a small angle of tilt, for example 4°, is reached the plate will displace the valve against the action of the spring 22. In the displaced position, the clutch 19 is connected to a relief line 24 and is disengaged. Accordingly, when the motor 17 reaches the said small angle of tilt, it is automatically disconnected from the shaft 13.

In the driving-off position shown, the pump 15 is at its smallest angle of tilt and the two motors 16 and 17 are at their maximum angle. For the control of the transmission, three cam or slot plates 26, 27 and 28 are fixed on a common shaft 25. The shaft 25 can be turned, through a lever 29, by a working piston 30 which is actuated by a pressure medium. In this example, the piston 30 is actuated, with follow-up servo control, by a manually operated lever 31. Naturally, automatic control would be possible instead of the manual control described.

The servo means shown is of a conventional nature. Initially the lever 31, when adjusted, moves a slide valve, shown connected to a lower pivot point on the said lever, in the required direction, e.g. to the right from the zero position of Fig. 1. As a result, the right-hand side of the piston 30 is subjected to fluid pressure from the line 20 and the piston is displaced to the left. Through a spring disposed around the piston rod, the upper pivot point of the lever 31 is also moved to the left. This motion is transmitted to the aforesaid slide valve which is drawn back into its zero position. Consequently, the piston 30 is brought to rest after a movement corresponding to the movement described by the adjustment of the lever 31.

The swash plate 32 of the pump 15 engages by means of a rod linkage 33 in the slot 34 of the cam plate 26. In the same way, the swash plate 35 of the motor 16 is engaged by a linkage 36 with the slot 37 of the plate 27. Finally, the swash plate 23 of the motor 17 is also engaged by a linkage 38 with the slot 39 of the plate 28.

The manner in which the transmission is regulated will now be described with reference to Figure 2, in which three variables are plotted against the ratio of the output speed *na* to the input speed *nl*. In the top part of the diagram, the variable is the ratio of the output torque M*a* to the input torque Ml, in the middle part the angle A of swash-plate tilt for the pump 15 (full line) and motors 16, 17 (broken lines) in degrees, and in the bottom part the pressure *p* in the axial-piston machines in Kp per cm^3.

To drive off, the shaft 25 is turned counterclockwise by the lever 31 and piston 30. By this means, the angle of tilt of the pump 15 is first increased (See the full line in the zone A of the middle part of Figure 2) by the section 40 of the slot 34. During this increase, the angles of tilt of the motors 16 and 17 remain at the maximum value, by reason of the shapes of the slots 37 and 39 (Figure 1). When the pump 15 has reached its maximum angle of tilt, it is kept there by the section 41 of the slot 34. In this zone B in Figure 2, the section 42 of the slot 39 reduces the angle of tilt of the motor 17 until a switching point S (Figure 2) is reached. At the point S, the swash plate 23 operates the valve 21 so that the clutch 19 is disengaged by

relief of the pressure through the line 24. The motor 17 is thus disconnected from the output shaft 13. To make this disconnection shock free, the section 43 of the slot 34 at the same time causes the angle of tilt of the pump 15 to be reduced, so that there is a brief increase in pressure (see the bottom part of Figure 2). As a consequence, the permanently coupled motor 16 is able to take up the necessary torque and the motor 17 is disconnected without shock.

After disconnection of the motor 17, the pump 15 is brought back (zone C in Figure 2) to its maximum angle of tilt. Further regulation is then carried out (in zone D) by reducing the angle of tilt of the motor 16 back to its minimum value by the section 44 of the slot 37. The vehicle has then reached its maximum speed. If it is required to reduce the vehicle speed, the regulation is carried out similarly, but in the reverse sequence. The conditions and associated regulating positions for intermediate ranges of vehicle speed can be seen from Figure 2.

The axial-piston machines 15-17 may in themselves be of known kind. Axial-piston machines of other known kinds may be employed, for example such with tilting housings. In this case, the control means, i.e. the valve 21, may be actuated by the tiltable housing of the motor.

In the case of a transmission with more than two motors, the motors of each kind are controlled similarly to the motors 16 and 17 respectively.

WHAT WE CLAIM IS:—

1. An infinitely variable hydrostatic transmission in a vehicle, comprising an axial-piston pump driven by the power unit of the vehicle and at least two axial-piston motors, wherein at least one motor is rigidly connected to the output shaft and at least one other motor can, while in a driving position, be coupled to the output shaft or uncoupled therefrom by a clutch, and the pump is arranged to be so adjusted, on uncoupling of the said other motor, that the said one motor can furnish the output torque required.

2. A transmission according to claim 1, wherein a clutch operated by auxiliary power is associated with the or each said other motor and the auxiliary power is controlled automatically in conjunction with the angle of tilt of the motor.

3. A transmission according to claim 1 or 2, wherein the angles of tilt of the pump and the motors are controlled together by cam or slotted plates from a servo-assisted operating lever.

4. A transmission according to claim 3, wherein, in the driving-off position, the pump is at its minimum angle of tilt and the motors at their maximum angle, the pump alone being first adjusted to its maximum angle and then the or each said other motor is adjusted to its minimum angle which is reached at the uncoupling point, at which the pump is also brought to a smaller angle of tilt, and after the uncoupling, is restored to the maximum angle.

5. A transmission according to claim 4, wherein the or each said one motor is restored gradually to its minimum angle of tilt after the pump has reached its maximum angle for the second or last time.

6. A transmission according to claims 4 and 5, wherein the tilting members of the pump and motors are connected through linkages to respective slot or cam plates on a common shaft rotatable by a servo-assisted piston controllable by an adjusting member.

7. A transmission according to any one of the preceding claims, wherein the or each said other motor is connected to the output shaft through intermediate gearing and a clutch which can be engaged against spring force by means of auxiliary fluid power controlled by a valve which, under the spring force, connects the clutch to the supply line for the fluid and, when actuated by the said motor, connects the clutch to a fluid-relief connection.

8. An infinitely variable hydrostatic transmission in a vehicle substantially as hereinbefore described with reference to and as shown in the accompanying drawing.

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(7651) Printed by Her Majesty's Stationery Office Press, Edinburgh, 1970.
Published by The Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.

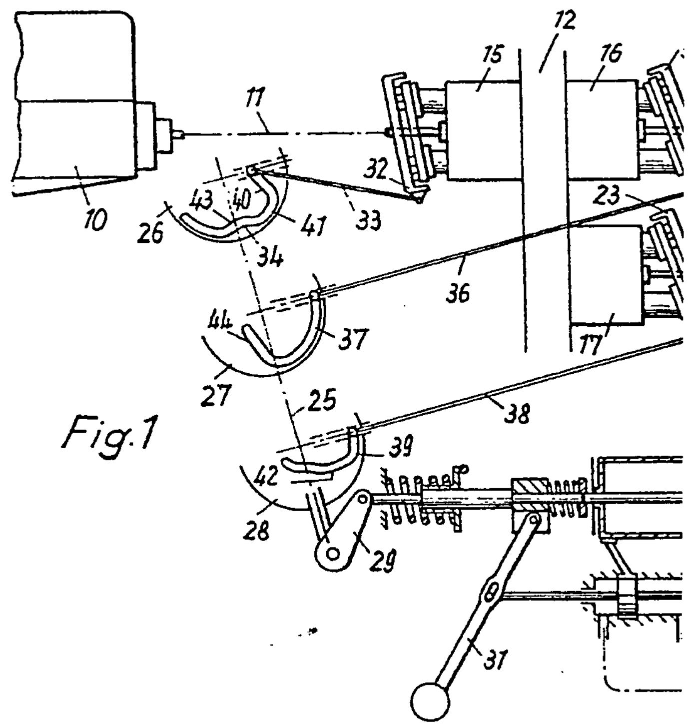
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Fig.1

1206196 COMPLETE SPECIFICATION

1 SHEET

This drawing is a reproduction of the Original on a reduced scale

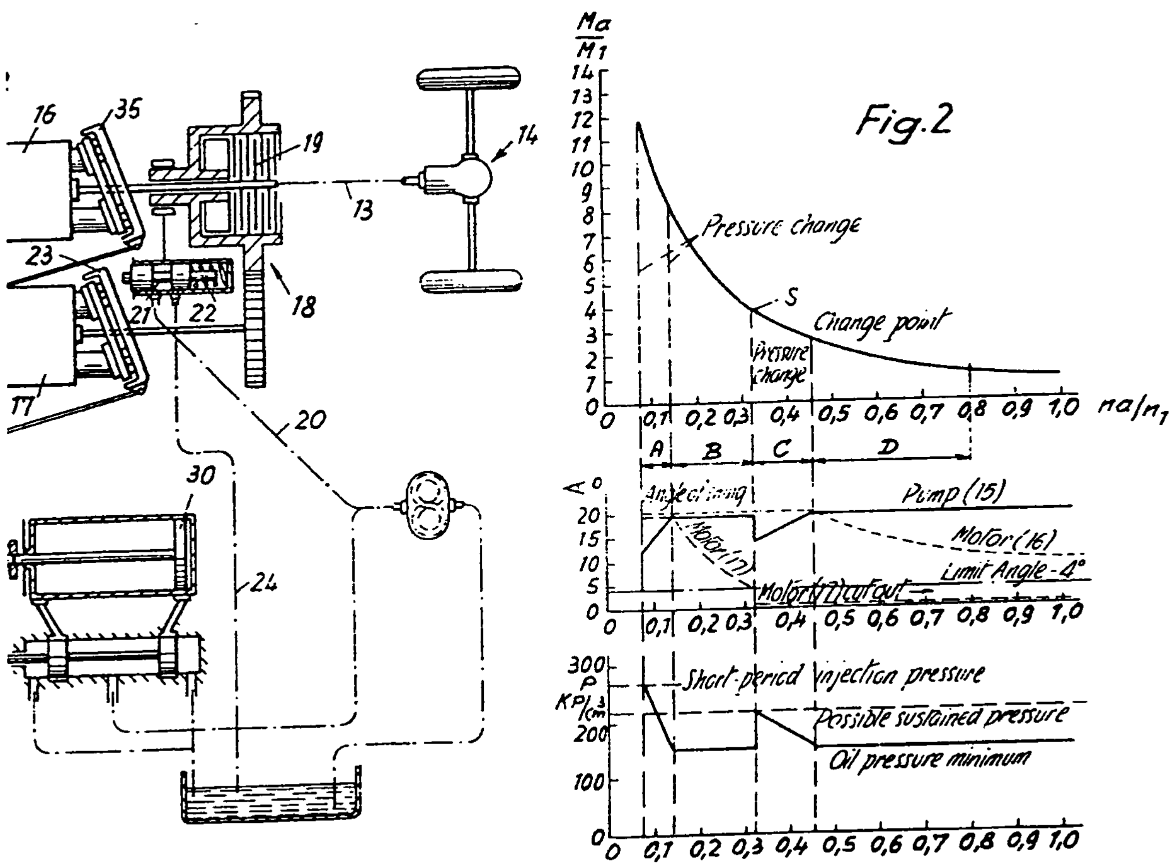

Fig.2

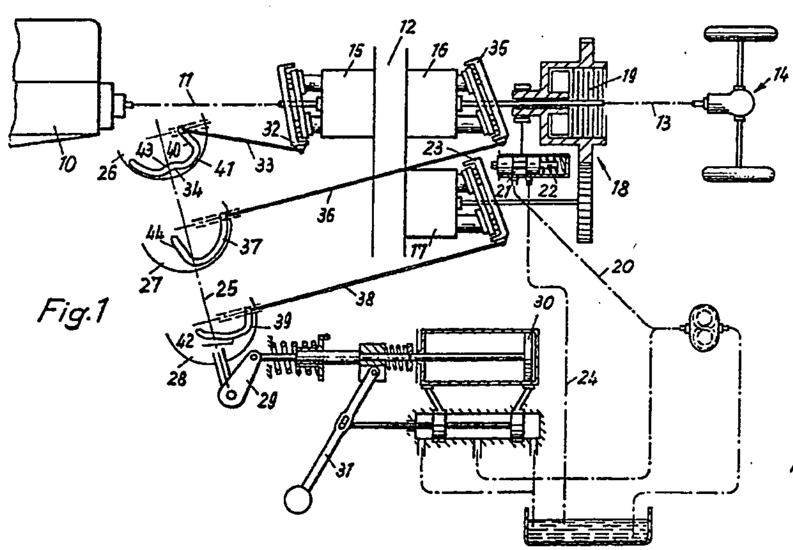
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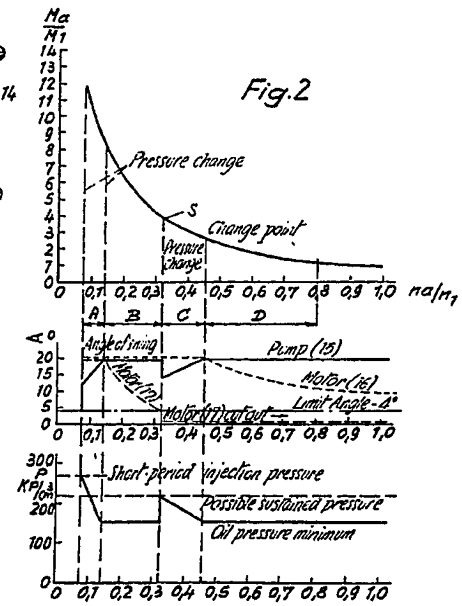
Fig.1


Ma/M1
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Angle of swing
Pump (15)
Motor (16)
Motor (17)
Limit Angle-A°
Motor (17) cut out
P KP/cm²
Short-period injection pressure
Possible sustained pressure
Oil pressure minimum

Fig.2